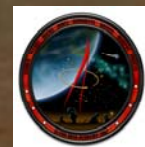
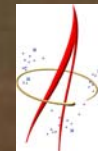


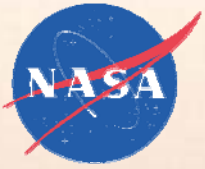
# MER Vision Data Analysis: Dust Concentration of Mars Dust Devils

*2007 NASA Academy at Glenn  
Final Presentation  
August 10, 2007*



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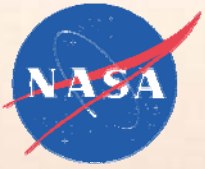


# Outline



- I. Introduction
- II. Problem Definition
- III. Approach
- IV. Results
- V. Conclusions
- VI. References
- VII. Acknowledgements





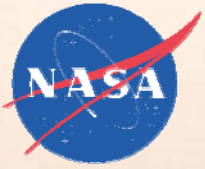
# I. Introduction

## Dust on Mars



- Martian dust: very fine-grained, adheres easily to surfaces
- Effects the solar spectrum and intensity
  - Important for designing solar cells
- Dust devils an interesting phenomenon
  - Swirling vortices of air that lift and transport dust
  - More frequent in spring and summer
  - Cleaned dust off Mars rover solar cells



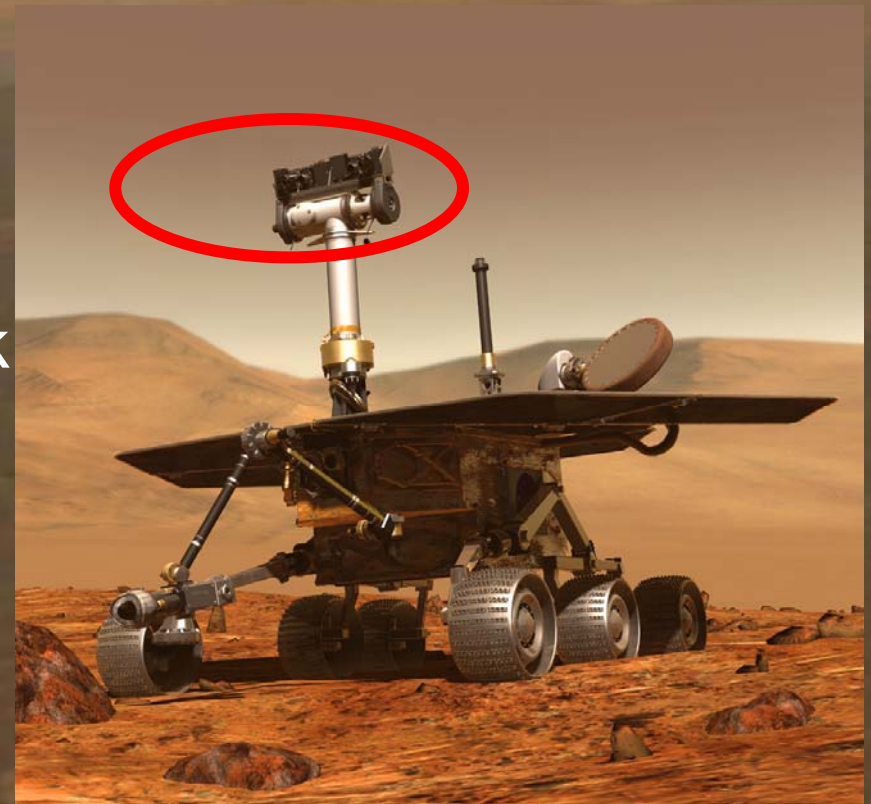


# I. Introduction

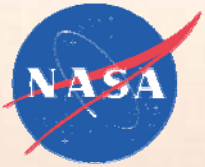
## MER Navcam



- Looking for dust devils
  - 21-frame movies, 7 - 20 minutes
  - Downlink compressed thumbnail images to check for dust devils
  - If dust devil present downlink entire sequence
- Navcam rad-cal images are digital light intensity measurements

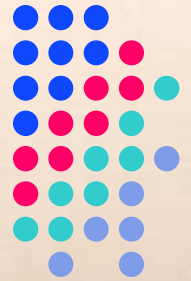






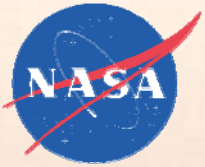
## II. Problem Definition

# Investigating Dust Concentration



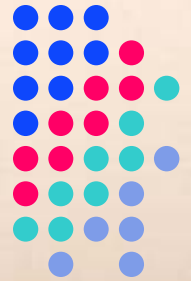
- Investigate Dust Concentration of Mars dust devils
  - Examine dust opacity,  $\tau$ 
    - How does  $\tau$  vary according to position?
    - How does  $\tau$  change in time as dust devil develops?





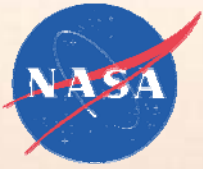
## II. Problem Definition

# Investigating Dust Concentration



- Since midterm poster session:
  - How is dust devil  $\tau$  different from  $\tau$  of the sky?
  - Distinguish dust devil in front of the sky from the background
  - Calculations without the assumption of same optical properties for dust devil dust as atmospheric dust



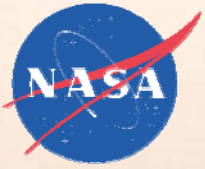


# III. Approach Optical Analysis



- To determine the opacity/concentration of dust in the dust devil
  - Compare the intensity of light seen through the dust devil with the intensity of light not passing through the dust devil
- Beer's Law describes the decrease in intensity due to the opacity,  $\tau$ , of the dust
  - $I_{\text{dust devil}} = I_{\text{ground}} e^{-\tau}$





### III. Approach Optical Analysis



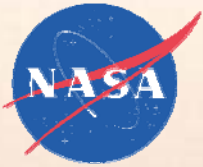
- Accounting for light scattered in from the sky, total intensity is a weighted combination of light reflected from the sky and the ground:

- $I_{\text{dust devil}} = I_{\text{sky}} + (I_{\text{ground}} - I_{\text{sky}})e^{-\tau}$

- $\tau = \ln \left[ (I_{\text{ground}} - I_{\text{sky}}) / (I_{\text{dust devil}} - I_{\text{sky}}) \right]$



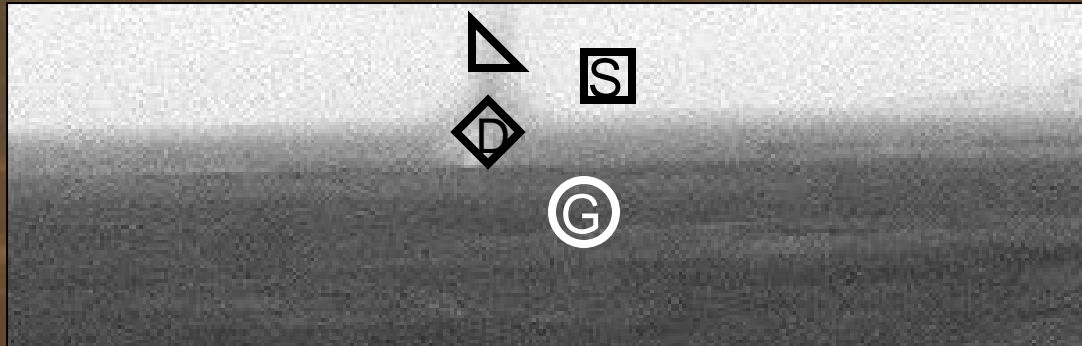




### III. Approach Calculating $\tau$



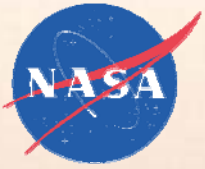
- Select pixels from image for intensity samples:
  - $I_{\text{ground}}$
  - $I_{\text{sky,}}$
  - $I_{\text{dust devil}}$  (with ground, not sky in the background)
- And more rigorous:
  - $I_{\text{sd}}$  (dust devil in front of the sky)



#### Legend

	$I_{\text{ground}}$
	$I_{\text{sky,}}$
	$I_{\text{dust devil}}$
	$I_{\text{sd}}$





### III. Approach Data Selection



- 1. To select data points from images, need to look at the enhanced image to find dust devil
- 2. Then get the actual data values from the non-enhanced image- tedious data selection process

1.

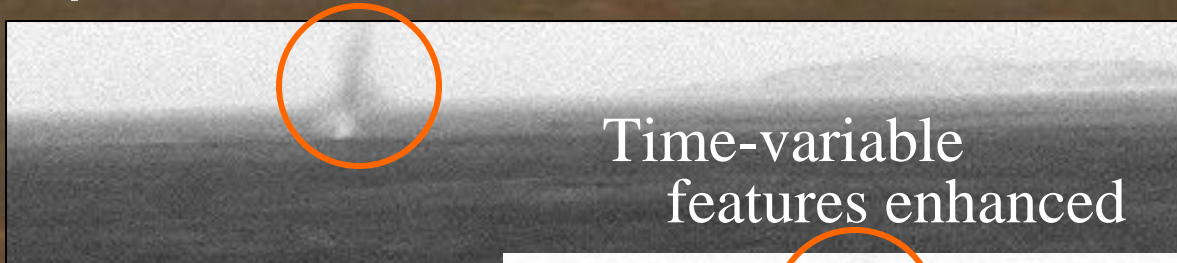
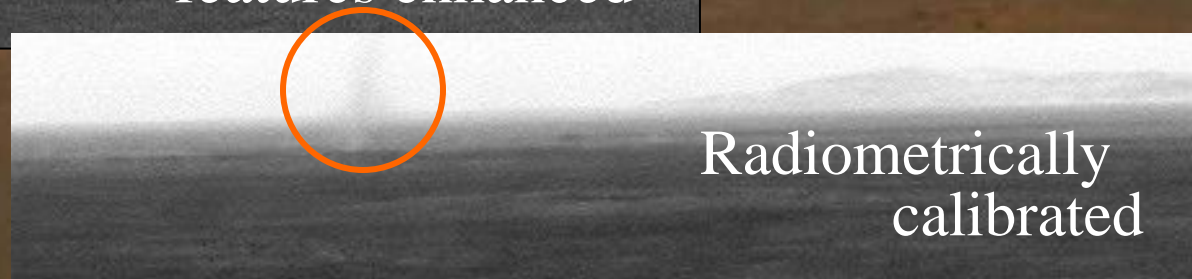
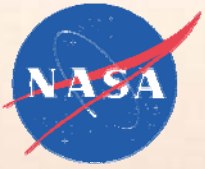


image by Mark Lemmon,  
Texas A&M

2.

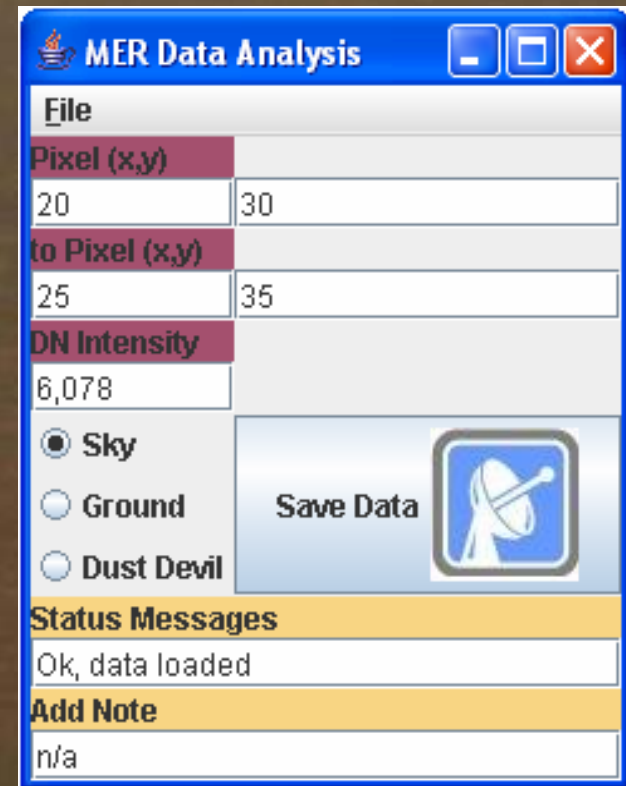


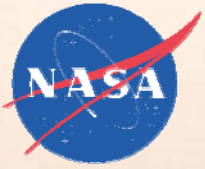


### III. Approach Data Selection

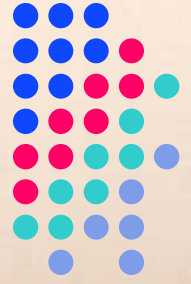


- Developed a simple GUI (Graphical User Interface) to aid in data selection and processing
- Allows user to open an image, select a block of pixels, and then save the data values with the average and a description in an excel-compatible format

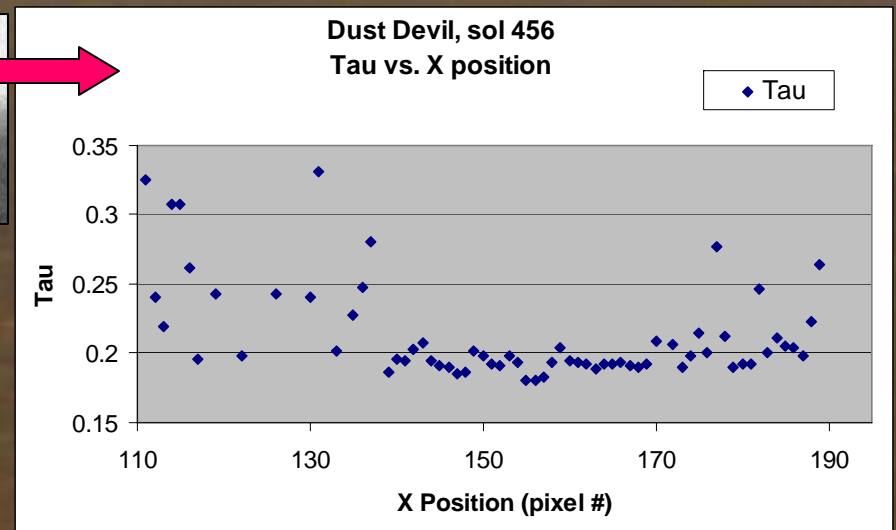
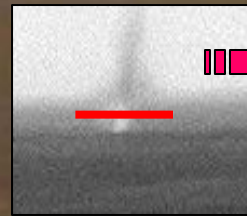




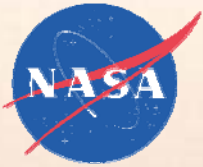
### III. Approach Displaying Data



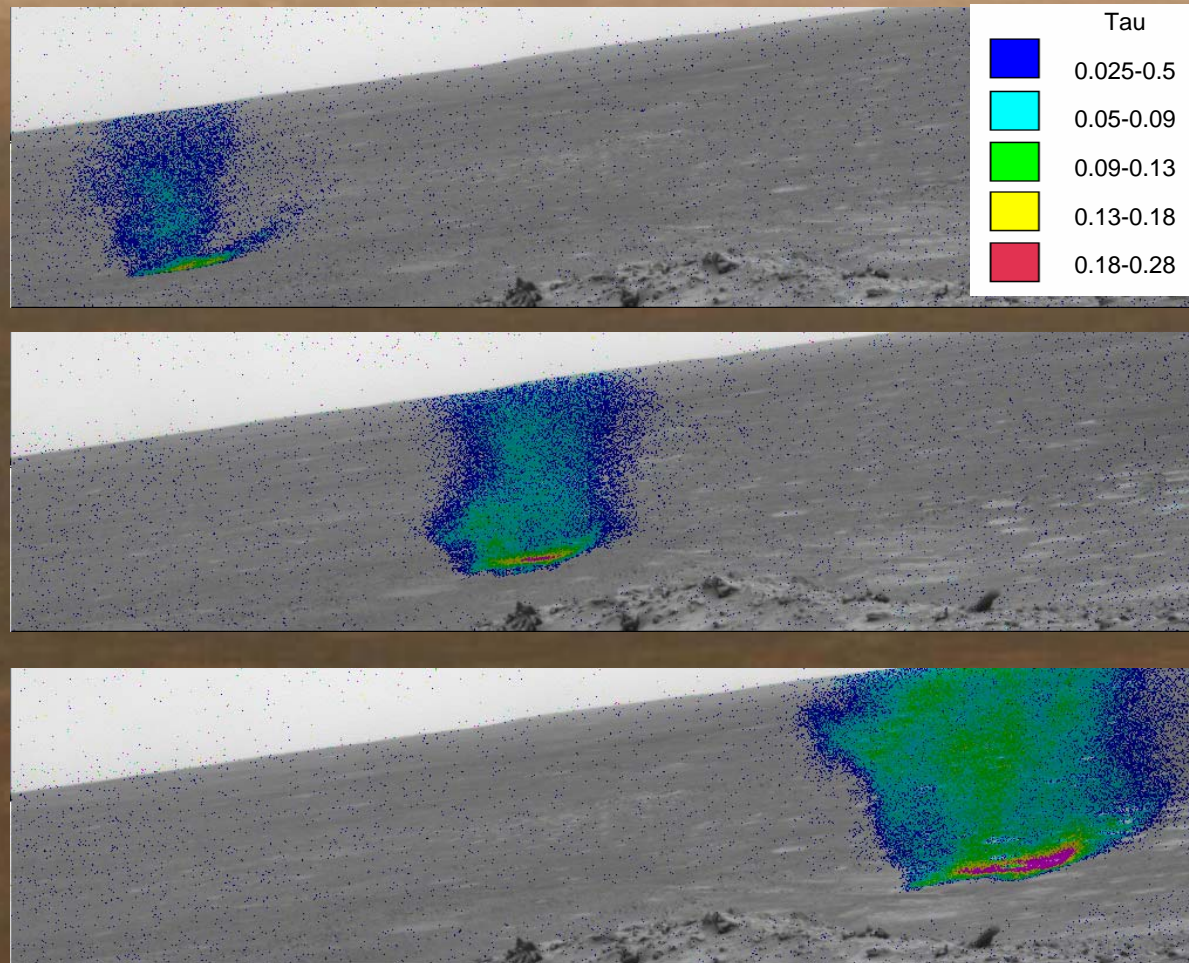
- Initial 1-D (horizontal distribution) results- not a clear presentation of data
- Wanted to present a clear visualization of  $\tau$  distribution in dust devils
- Coded a .PNG image encoder to write images pixel by pixel

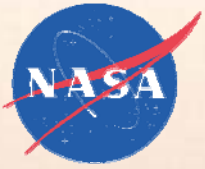






# (IV. Early Results) Tau Distribution



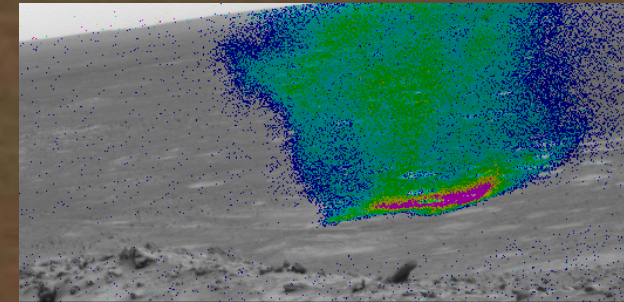


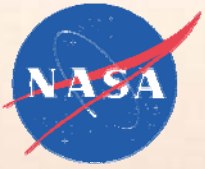
# III. Approach

## Making New Images



- Read original image
- Get intensity values
  - $I_{\text{sky}}$  : filter intensities above 5000, take average
  - $I_{\text{ground}}$  : from previous frame
  - $I_{\text{dustdevil}}$  : subtract to find change from last frame
- Calculate  $\tau$  for each pixel
- Display algorithm
  - Display color by  $\tau$  value
  - Cutoff negative  $\tau$  values, and pixels that haven't changed since last frame

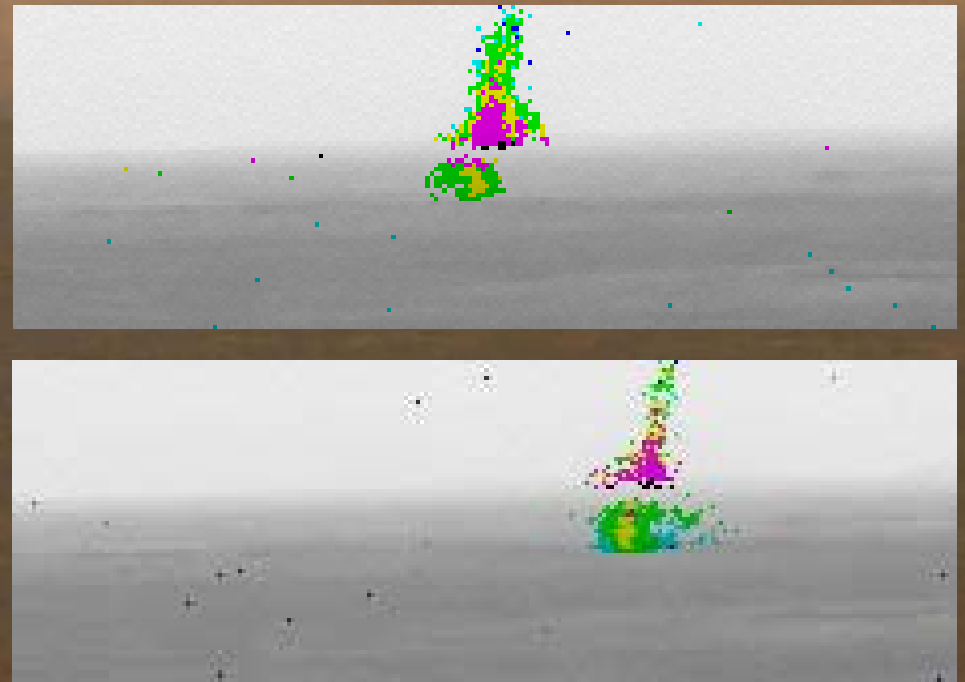




## IV. Results



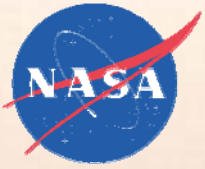
- Distinguishing dust devil in front of the sky
- More rigorous calculations not assuming same properties for dust in dust devil as in atmosphere



Sol 640, frames 1 and 2



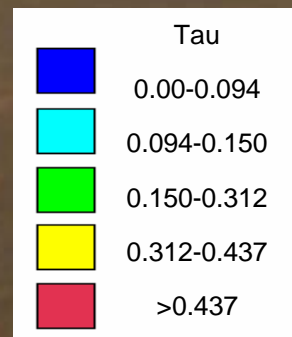
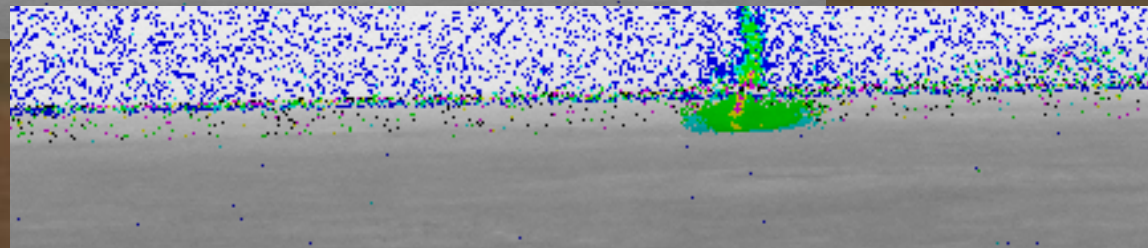
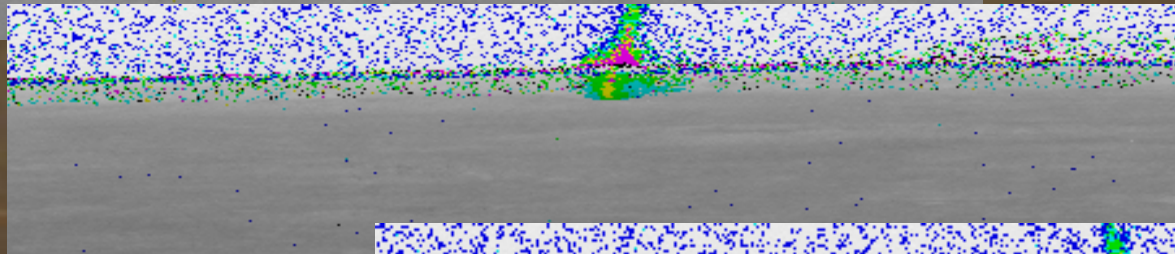
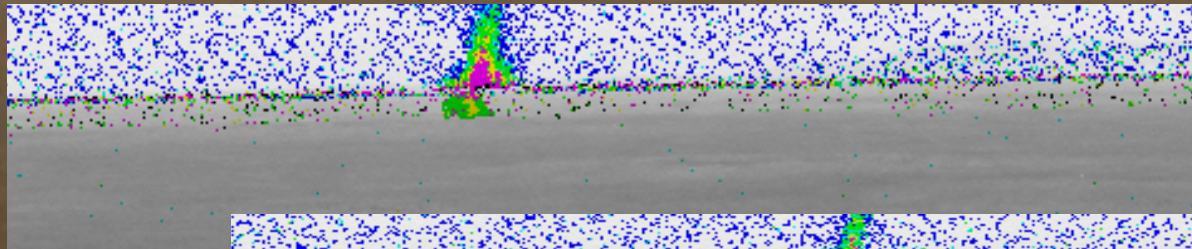




## IV. Results



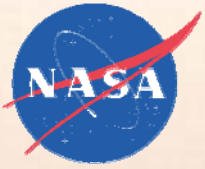
- Showing  $\tau$  of the sky and the dust devil



Sol 640, frames 1-3



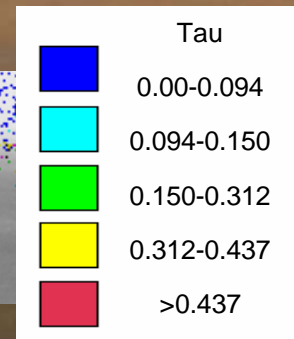
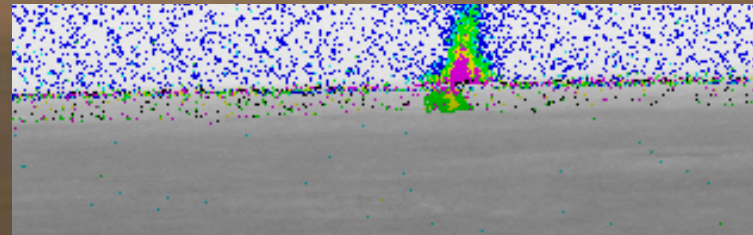




## IV. Results

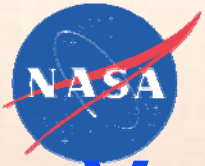


- Showing  $\tau$  of the sky and the dust devil
- About 10-20% difference



sol	frame	Avg Dust Devil Tau	Avg Sky Tau	Tau Difference
640	1	0.12263692	0.1281357	-0.005499
640	1	0.12651319	0.13973	-0.013217
640	2	0.13820017	0.2116821	-0.073482
640	3	0.19402165	0.177779	0.0162427
640	4	0.13292625	0.0897636	0.0431627

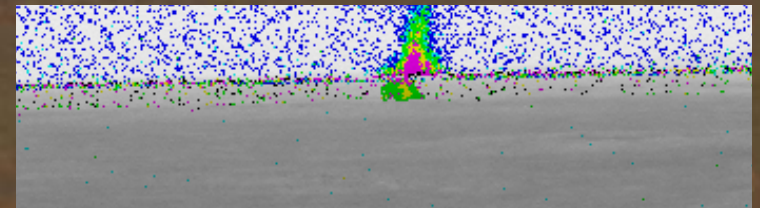




## V. Conclusions



- Expected dust devil to be more opaque and have  $\tau$  larger than sky  $\tau$
- Very similar  $\tau$  values for sky and dust devil
- Different results for different frames of the dust devil images
  - Could that measurements are small and sensitive so there is a lot of noise
  - Or very sensitive to selection of pixel samples for sky, ground, especially around the horizon area



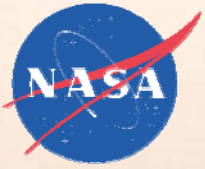


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## VII. Acknowledgements



- Geoffrey Landis
- Massachusetts Space Grant Consortium
- NASA Academy Staff
- Kamara Brown
- Michael Lamberty
- Dr. David Kankam

